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Stone Walls: Stories from Minnesota's Geologic Past

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Some may know what they seek in school and church,
And why they seek it there; for what I search I must
Go measuring stone walls, perch on perch
— Robert Frost, "A Star in a Stoneboat" (1969)

For many, the term *stone* has an uncommunicative context — *stone deaf*, *stone cold*, or *stony silence*, but to the trained eye, stones contain wonderfully illustrated short stories of fire and ice; life and death; violent upheaval and persistent erosion. Every stone has a story to tell, but Mother Nature set no agenda in recording the history of Earth in stone. While the ultimate task of geologists is to unravel and connect the stories, the interpretation may be flawed or even biased.

As literature, Mother Nature's autobiography is a mixed genre from breathtaking thrillers to tedious yarns and, unfortunately, the story is seldom complete due to the continuous recycling of Earth's material by weathering, erosion, and tectonic forces. Considering the Earth is over 4½ billion years old, the earliest stories are generally incomplete, with some stories forever lost in time. Geologic stories are not arranged in chronological order or found in any particular location, but rather are scattered across the face of the earth, like pages torn from a history book and scattered by the winds.

It is important to bear in mind Mother Nature's collections of stories are not preserved solely for academic use, and it would be foolish for humans to ignore the wisdom written in the stones. Among those are the quarry stone and field stones, which can be seen in the stone walls on the campuses of the College of Saint Benedict and Saint John's University. These walls reveal stories of Minnesota's geologic past.

When describing Earth's history, geologists traditionally begin with the oldest and proceed toward the most recent. I am going to break from tradition, very briefly, to describe the most recent, major geologic event in the history of the Earth — the Pleistocene Ice Ages. The present landscape of central Minnesota is largely the result of this glacial activity, and ultimately responsible for the exposure of the stone quarried in the area and for the field stones, which seem to "sprout" in the fields each spring.

MINNESOTA'S ICE AGE

The glacier was God's great plough…set at work ages ago to grind, furrow, and knead over, as it were, the surface of the Earth
— Louis Agassiz, *Geological Sketches* (1866)

With the onset of an ice age, ice caps expand, tongues of ice (glaciers) inch ever so slowly over high latitude landscapes, and sea level gradually drops. An ice age also means plant and animal species migrate, selectively adapt, or become extinct. Even though the Ice Ages seem a relic of Earth's distant past, it is important to remember that ice ages have occurred more than once in Earth's long history and, according to many geoscientists, humankind is presently living within a glacial interlude.

Between one million and 12,000 years ago, Minnesota experienced four major glacial advances. The glacial stages are known as the Nebraskan (1 million to 900,000 years before present; BP), Kansan (700,000 to 600,000 BP), Illinoian (300,000 to 200,000 BP), and Wisconsin (50,000 to 10,000 BP), and each is represented by periodic growth and decay of ice and changing climatic conditions. The Wisconsin glaciation left the most visible "footprint" on the landscape and, in Minnesota, is represented by four separate ice lobes: Wadena, Rainy, Superior, and Des Moines.

The Wadena Lobe advanced southward from the Winnipeg area and left behind the limestone-rich sands and gravels that constitute the Alexandria and Itasca moraines and the drumlin fields of Otter Tail, Wadena, and Todd Counties. The Rainy and Superior Lobes advanced southwestward from the area around Lake Superior and deposited the cobbles and boulders of basalt, gabbro, granite, banded iron formation, red sandstone, slate, and greenstone. Each spring new cobbles and boulders, derived from the Lake Superior region, emerge from their extended sleep across farm fields of central Minnesota to be collected before the spring planting. The Des Moines Lobe originated in northwestern Minnesota and advanced southeasterly into north-central Iowa, leaving a finer-textured till of limestone, shale, and granite fragments from which the prairie soils of the region developed. In addition, glacial movement scoured away the pre-glacial landscape to reveal the underlying granites and gneisses, which are now quarried in the region for dimension stone.

The rolling topography surrounding Saint John's University, with its hummocky hills (kames), lakes (kettles), and wetlands, is the result of Wisconsin glaciation. The boulders, which the monks of Saint John's picked from the fields and incorporated into the walls around campus, were brought down from the north by the advancing ice. Even though the boulders appear to be chaotic amalgamations, each boulder and cobble can be traced to a specific source based on its distinctive mineralogy. The landscape continues to undergo modification by both human and natural processes. Although changes in the landscape seem exceedingly slow in the sense of human time; the change occurs in a "blink of the eye" on the scale of geologic time.

A mixture of granites, gneisses, sandstones, shales, basalts, and banded iron in a rock wall near the power plant on the campus of Saint John's University. (Photo: Larry E. Davis)

MINNESOTA'S OLDEST ROCKS

… no vestige of a beginning, no prospect of an end
— James Hutton, *Theory of the Earth* (1785)

In his book, *Annales veteris testamenti, a prima mundi origine deducti* (Annals of the Old Testament, Deduced From the First Origins of the World), 1650, James Ussher, Archbishop of Armagh, Primate of All Ireland, and Vice-Chancellor of Trinity College in Dublin, established the first day of Creation as Sunday, 23 October 4004 BC (Gould, 1999). A 6,000-year time scale continues to serve as a foundation for young-Earth creationists' judgments about Earth's history, but according to James Hutton (1726–1797), a Scottish physician and the father of modern geology, the Earth is exceedingly old.

Modern radiometric dating of meteorites has firmly established the age of the Earth at over 4.5 Ga (billions of years). However, rocks in the Earth's crust are continually being recycled by tectonics and the processes of weathering, which reset the radiometric clock. To date, the oldest rock discovered on Earth is the Acasta Gneiss in northwestern Canada near Great Slave Lake, dated at 4.03 Ga. Minnesota's oldest rocks, the Morton and Montevideo gneisses, have been dated at 3.55 Ga and 3.45 Ga, respectively. These are the oldest rocks in the United States.

The Morton Gneiss, Minnesota's oldest rock. The red bands are composed primarily of orthoclase feldspar; black bands are biotite mica and amphibole, and the grayish zones are quartz. Excellent examples of the Morton Gneiss can be observed in walls around Mary Commons on the College of Saint Benedict campus. (Photo: Larry E. Davis)

Quarried in the Minnesota River valley, the Morton Gneiss can be found in buildings and cemeteries across the nation. No two pieces of the rock are the same and one needs only a modest imagination upon which to base a description. For me, descriptions of rock always seem to center on something edible; consequently my portrayal of the Morton Gneiss is that of strawberry, chocolate, and vanilla ice cream slightly softened and delicately stirred. Of course, in truth, the origin of the Morton Gneiss was far from delicate and geologically is described as a coarsely crystalline metamorphic rock with a mineralogy suggesting it was originally a granite that slowly crystallized from a silica-rich magma tens of kilometers beneath the Earth's surface. (Although the age is not disputed, there is some debate about some of the specifics regarding the "parentage" of the Morton Gneiss. This should not be seen as a weakness in science, but rather as the essence of science.) The alignment of the mineral grains, and eddying pattern of colors, indicates that the original granite was subjected to enormous temperatures and pressures deep below the Earth's surface.

The Morton Gneiss is part of the Superior geological province of the Canadian Shield, a large region of extremely old bedrock that constitutes the heart of the North American continent. The Superior province, along with six additional geological provinces, located mostly in Canada, reveal an ancient history of tumultuous mountain building and volcanic activity. The deeply-rooted mountains of the Canadian Shield have been eroded to their current low topographic relief with only occasional glacially-scoured ridges and knolls of granites and gneisses left as representatives of that which may have been the highest mountains on Earth. In spite of the Shield's violent geological past, today the region is tectonically stable and free of earthquakes and volcanic eruptions.

Quarry stone in a wall near Mary Commons on the campus of the College of Saint Benedict. The dimension stone used in the construction of the wall consist of granites and gneisses common to central and southwestern Minnesota. (Photo: Larry E. Davis)

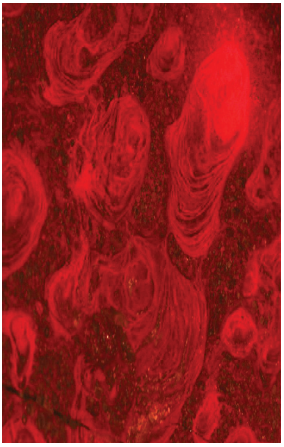
THE EARTH'S CHANGING ATMOSPHERE

Every day brings a chance for you to draw in a breath, kick off your shoes, and dance
— Oprah Winfrey, *O Magazine* (2003)

There was a time in Earth's early history in which drawing a breath and dancing would have been extremely hazardous. Geochemical analyses indicate the early Earth had a reducing atmosphere (as opposed to today's oxidizing atmosphere), rich in carbon dioxide and methane, with little or no oxygen. One line of evidence of an oxygen-depleted atmosphere is the lack of iron in Archean (3.8–2.6 Ga) sediments. Iron is very soluble under reducing conditions, but insoluble under oxygen-rich conditions.

The chemical transformation of the atmosphere began about 2.6 Ga and continued until about 1.8 Ga. The buildup of oxygen in the atmosphere is recorded in banded iron formations (BIF) found worldwide, including northern Minnesota. Deposits of hematite and quartz represent the precipitation of dissolved iron from sea water as the dissolved oxygen content of the water increased. After 1.8 Ga, banded iron formations are rare, but terrestrial red-beds become increasingly common, suggesting iron is now oxidizing and precipitating in soils and rocks.

The transformation of Earth's atmosphere was due to action of cyanobacteria, Earth's oldest life forms, which utilize CO_2 and release O_2 as a waste product during photosynthesis. Slightly crinkled layers of cyanobacteria are often preserved as cabbage-like mounds called stromatolites, and they range in size from a few millimeters to several meters. Uncommon today, due to the grazing action of snails, stromatolites are common fossils in banded iron formations and early Paleozoic carbonate rocks in Minnesota.



Small stromatolites in a polished slab of the Biwabik Iron Formation from the Mesabi Range in northern Minnesota. (Photo: Larry E. Davis)

Banded iron formations (BIF) are not found in central Minnesota, but cobbles and boulders of BIF are fairly common, having been transported and deposited by the Pleistocene glaciers. Today, one only needs to pick through the cobble- and boulder-strewn fields of the region to find examples of this spectacular and unusual rock. However, one needs to take caution in selecting the boulder to carry home, as a piece of BIF is nearly twice as heavy as an equal-size piece of granite or gneiss.

A glacial deposited boulder of banded iron formation (BIF) used in the construction of a stone wall near the Liturgical Press on the campus of Saint John's University. The dark gray layers are precipitated hematite, an ore of iron, and red layers are jasper, a cryptocrystalline form of quartz. The precipitated hematite provides evidence of the chemical transformation of Earth's atmosphere 2.5 billion years ago. (Photo: Larry E. Davis)

MINNESOTA'S PENOKEAN MOUNTAINS

Mountains are earth's undecaying monuments.
— Nathaniel Hawthorne, *The Notch of the White Mountains* (1868)

As one drives westward across eastern Colorado, the view to the foreground, of mountains rising abruptly and majestically out of the plains, is certainly representative of Nathaniel Hawthorne's description. But Hawthorne's description of mountains as undecaying monuments is geologically inaccurate, for mountains, like the monuments of human civilization, do eventually decay. Like an archeologist who unearths the secrets of ancient civilizations, geologists often have "to dig" to discover the secret interiors of ancient mountain ranges. Fortunately for geologists in central Minnesota, glaciers have done the digging.

We have already learned of Minnesota's earliest mountain building as revealed by the Morton Gneiss, but Minnesota experienced a second mountain-building event approximately 1.9 Ga. Geologists refer to this event as the Penokean Orogeny (mountain building). The earliest stages of the orogeny involved the initial stages of splitting and separation, termed rifting, of the North American continent to form a basin similar to today's Red Sea, where the Arabian Peninsula is rifting from Africa. Volcanic activity was common in and around the basin, and sediments filled the basin.

Eventually tectonic motion changed, causing a cessation of rifting and the initiation of continental convergence. Due to the extreme temperatures and pressures associated with this collision, the volcanic and sedimentary rocks that had filled the basin were intensely folded, like squeezed taffy, pushing mountain tops skyward and the mountain's "roots" downward. As the continental crust continued to thicken, the geothermal temperatures in the deeply buried rocks increased to the point where rocks began to melt, forming silica-rich magmas. Like a gigantic lava-lamp, magma plumes rose upward through the overlying folded rocks to within 15 km of the surface. The silica-rich magmas slowly cooled and crystallized to produce crystals of feldspar, quartz, and mica, and the slower the cooling, the larger the crystals. The differences in magma chemistry of each plume produced distinctive rock units. In eastern Stearns County these distinctive rock units are known as the Reformatory Granodiorite, the St. Cloud Red Granite, the Rockville Granite, and the Richmond Granite, all of which are extensively quarried. These are the rocks that give St. Cloud its nickname — "Granite City."

Granite quarry, Waite Park circa 1900. (Photo: Stearns County Historical Society)

The granitic rocks, which formed the core of the Penokean Mountains, are quite massive and contain relatively few fractures when compared with the rocks that would have surrounded them. The surrounding rocks were more susceptible to weathering and were slowly eroded away. The hardness of the minerals in the granites also made them more resistant to the erosive scouring of glaciers and, as such, can be observed as resistant outcrops of bedrock knobs on the present-day topography.

Glacially-scoured granites at Quarry Park near St. Cloud, MN. (Photo: Larry E. Davis)

A close-up view of the interlocking pattern of minerals typical of granites quarried in central Minnesota. The pinkish-white minerals are feldspars, with the glassy crystals of quartz and small "books" of biotite mica filling the intervening spaces. Numerous examples of a wide spectrum of granites can be observed in the walls inside Mary Commons on the campus of the College of Saint Benedict and stone pavers at the entrance to the Abbey Church on the campus of Saint John's University. (Photo: Larry E. Davis)

MINNESOTA'S VOLCANIC PAST

We are dancing on a volcano
— Words uttered by Comte de Salvandy
at a fete given by the Duke of Orleans
to the King of Naples, 1830

Between 1.2 and 1.1 Ga, the North American continent again experienced a rifting event, known as the Mid-Continent Rift, which extended from the eastern end of present-day Lake Superior to northeastern Kansas. Fluid, basaltic lavas, rich in iron and magnesium — similar to lavas flowing in Hawaii and Iceland — poured out from fissures along the margins of the rift. Cooling rapidly at the Earth's surface, the lavas formed finely-crystalline, dark-colored basalts. The cooling was so rapid, gases in the lava were trapped to form rounded spaces, called vesicles, in the basalt.

Hundreds of basaltic lava flows now form the North Shore Volcanic Group and are easily observed in the bays and state parks along Lake Superior's northern shore. The upper surfaces of the lava flows are easy to recognize due to the vesicular texture (like a frozen, frothy head on a mug of beer). In places where the iron- and magnesium-rich magmas failed to reach the surface, the cooling and crystallization occurred much more slowly, forming coarsely-crystalline, dark-colored gabbros, which make up many of the bluffs around Duluth. Cobbles of these rocks were eventually transported by glaciers into central Minnesota and are seen sporadically in the rock walls at Saint John's University.

A cobble of vesicular basalt, which formed near the top of a lava flow in the Lake Superior region. (Photo: Larry E. Davis)

As water flowed into the rift basin, sediments (gravel, sand, silt, and clay) were again deposited as layers across the basin floor. Under the increasing pressure of overlying sediment, the sediment was compressed to form reddish- to greenish-colored conglomerates, sandstones, and shales. Exposures of these sedimentary rock units, the Fond du Lac Formation and Hinckley Sandstone, can be observed in outcrops around and south of Lake Superior. Easily eroded, these sedimentary rocks provided much of the finer sediment transported southward by the Wisconsin glaciation. Occasionally, one can observe larger sedimentary cobbles and boulders in the fields of central Minnesota, or among the rocks in the walls at Saint John's University.

Sandstone cobble in a wall at Saint John's University. Less resistant to weathering, the harsh, wet Minnesota winters create small cracks and fractures that slowly break the rock apart, thus creating weakness in the stone walls. (Photo: Larry E. Davis)

MINNESOTA'S TROPICAL SEAS

It has long been a fact familiar to geologists, that, both on the east and west coasts of the central part of Scotland, there are lines of raised beaches, containing marine shells of the same species as those now inhabiting the neighbouring sea.
— Charles Lyell, *Principles of Geology* (1830)

Dolostone, a carbonate-rich rock that formed in warm, shallow seas, can be found surrounding the statue of Mary in "the Grotto" on the College of Saint Benedict campus. (Photo: Larry E. Davis)

Approximately 570 million years ago, Laurentia, the proto-North American continent, joined with other landmass and was situated near the equator. Most of the Earth's landmass at that time consisted of low-relief exposures of ancient granites and gneisses, free of any flora and fauna as the terrestrial ecosystem had yet to evolve. A slowly rising sea flooded all but a few highland areas. This first great deluge is known as the Sauk Transgression. As the sea transgressed across the landscape, ancient granites and gneisses were eroded. Then, on top of this eroded landscape, extensive sheets of sand were deposited. As the seas deepened deposition patterns changed, resulting in the formation of dolostones and limestone. Limestones and dolostones reveal abundant fossils and a record of the early evolution of life on Earth. A pattern of rising and falling sea level occurred repeatedly across the Minnesota landscape and sediments deposited in these ancient tropical seas are well exposed in southeastern Minnesota, where they are quarried for building stone and construction materials.

EPILOGUE

Stop and smell the roses
— Ringo Starr, 1981

Sometimes it seems humanity has become indifferent to, and separated from, the natural world. Information speeds around the world in nanoseconds and our lives are increasingly controlled by electronic devices. Time seems to slip through our fingers, but at some point, we should "stop and smell the roses."

As a start, take a stroll along a stone wall and let your hand slide along the surface. Feel the texture of the stone. Look for patterns in the various shapes and colors of minerals in the stone. Ask the question, "So stone, what is your story? Where are you from? How did you get here?" The stories are not always easy to hear, or to understand, and some we will never know, for Mother Nature does like to keep her secrets.

Still, the story of the world, of Minnesota, and, perhaps, of us is there if we take the time to slow down and listen.

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